

# Waveguide-based External Cavity Semiconductor Laser Arrays

## A Smart Optical Systems project

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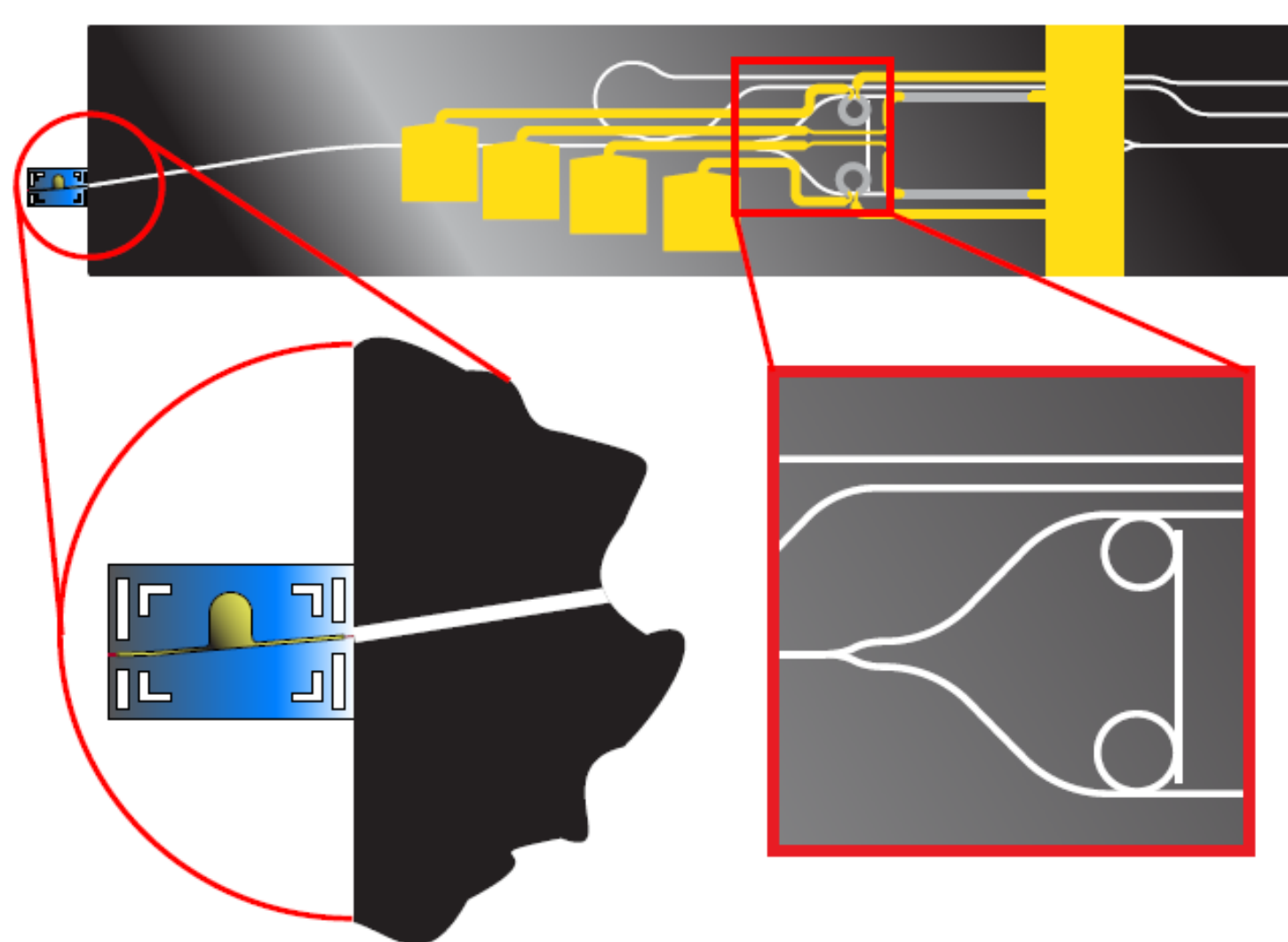
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### Waveguide based external cavity semiconductor laser (WECSL)

#### Goal

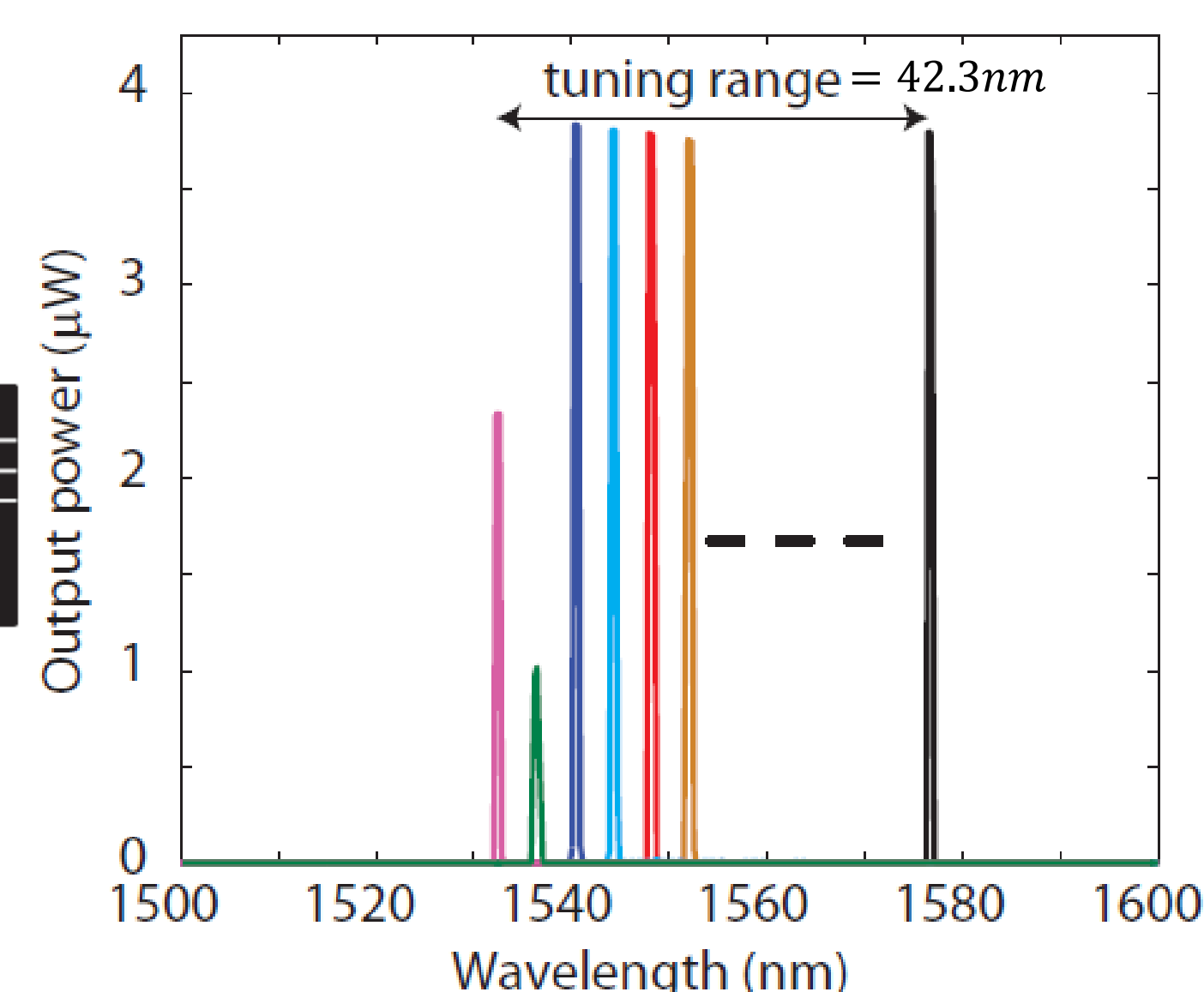
- Widely tunable
- Single longitudinal oscillation
- Narrow linewidth
- Small footprint (~mm<sup>2</sup>)



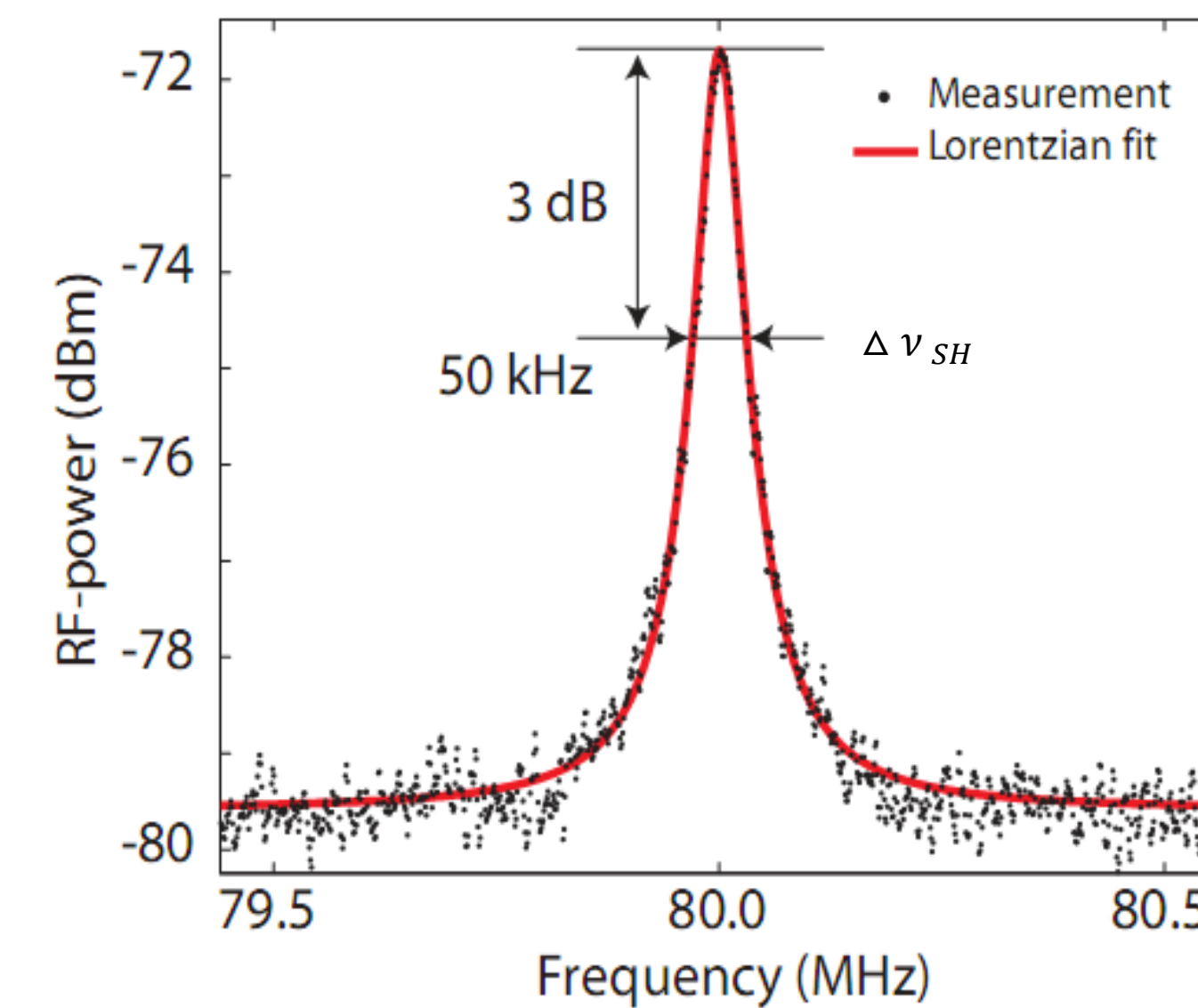
#### Techniques

- Low loss external waveguide circuit
- Mirror-like device for spectrally filtered feedback (double-ring resonators)
- Hybrid integration of active material (InP) and passive material (Si<sub>3</sub>N<sub>4</sub>)

#### Measured tuning WECSL output



#### Self-heterodyne measurement of line width



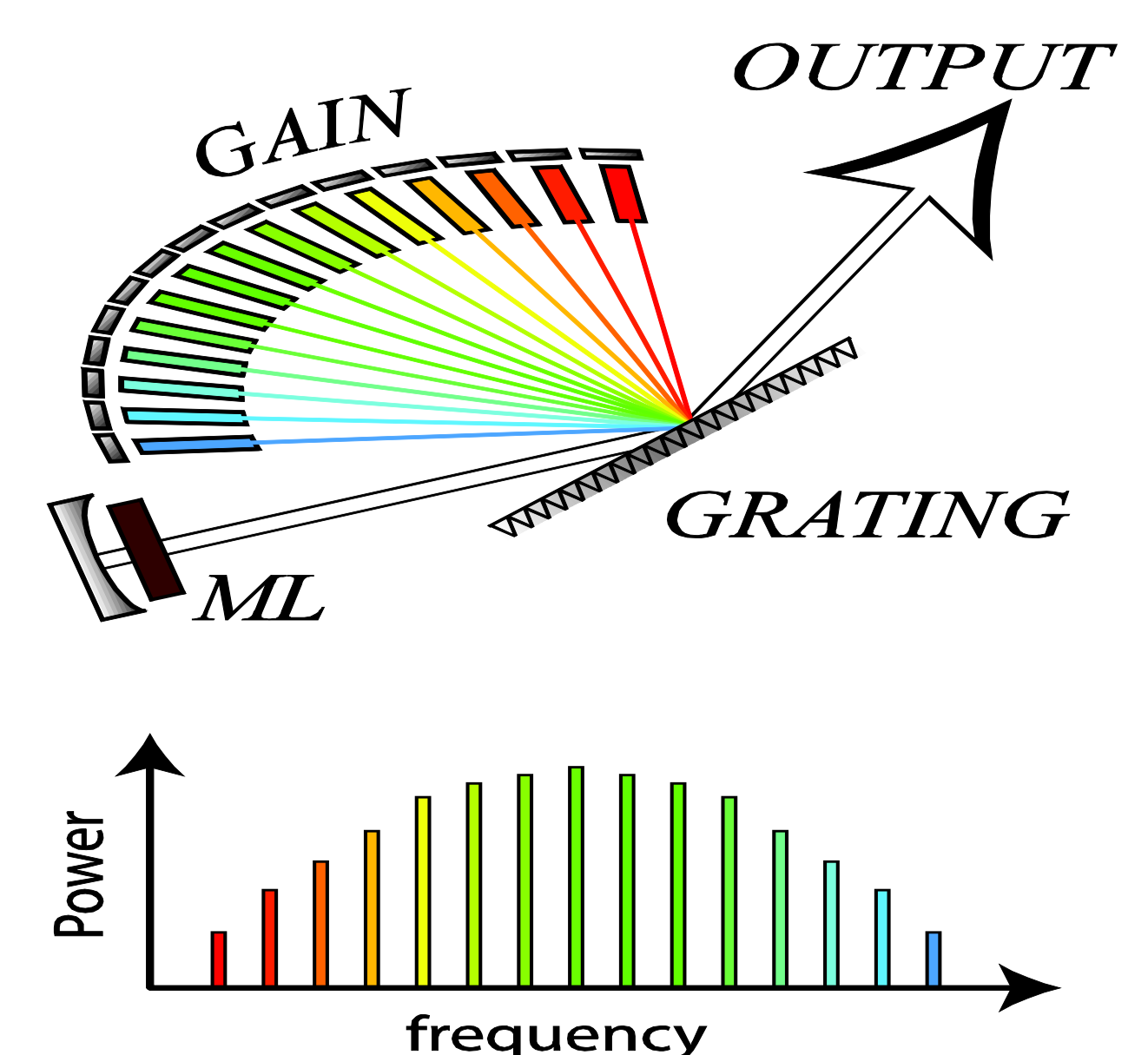
- Very narrow linewidth achieved

$$\Delta \nu = \frac{1}{2} \Delta \nu_{SH} = 25 \text{ kHz}$$

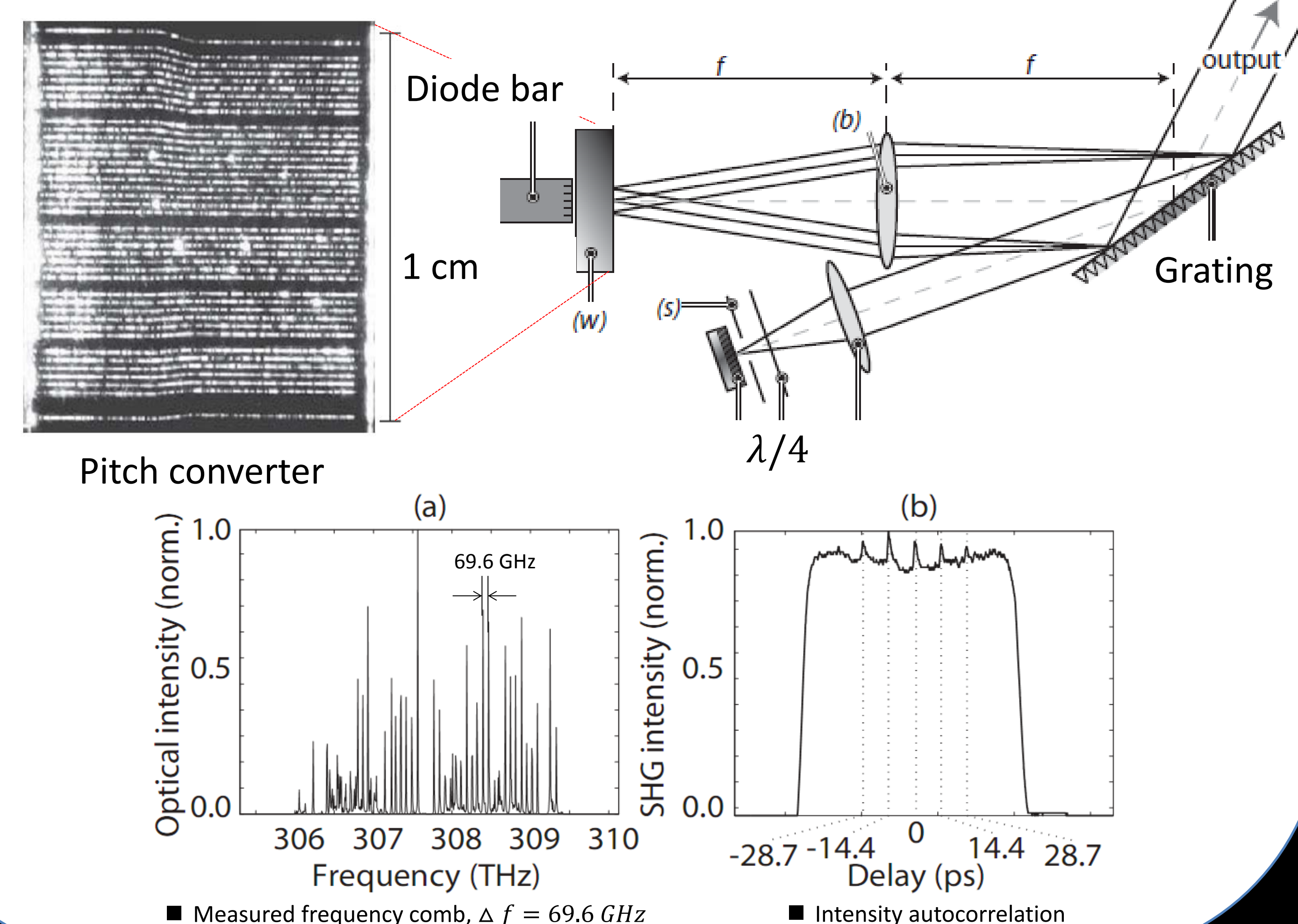
### Separate gain (SEGA) mode locking

#### Goal

- High repetition rate mode locked laser
- More elements = Higher output power
- Broader spectrum = reduced pulse duration



#### Experiment setup



### Injection locking of a WECSL

#### Goal

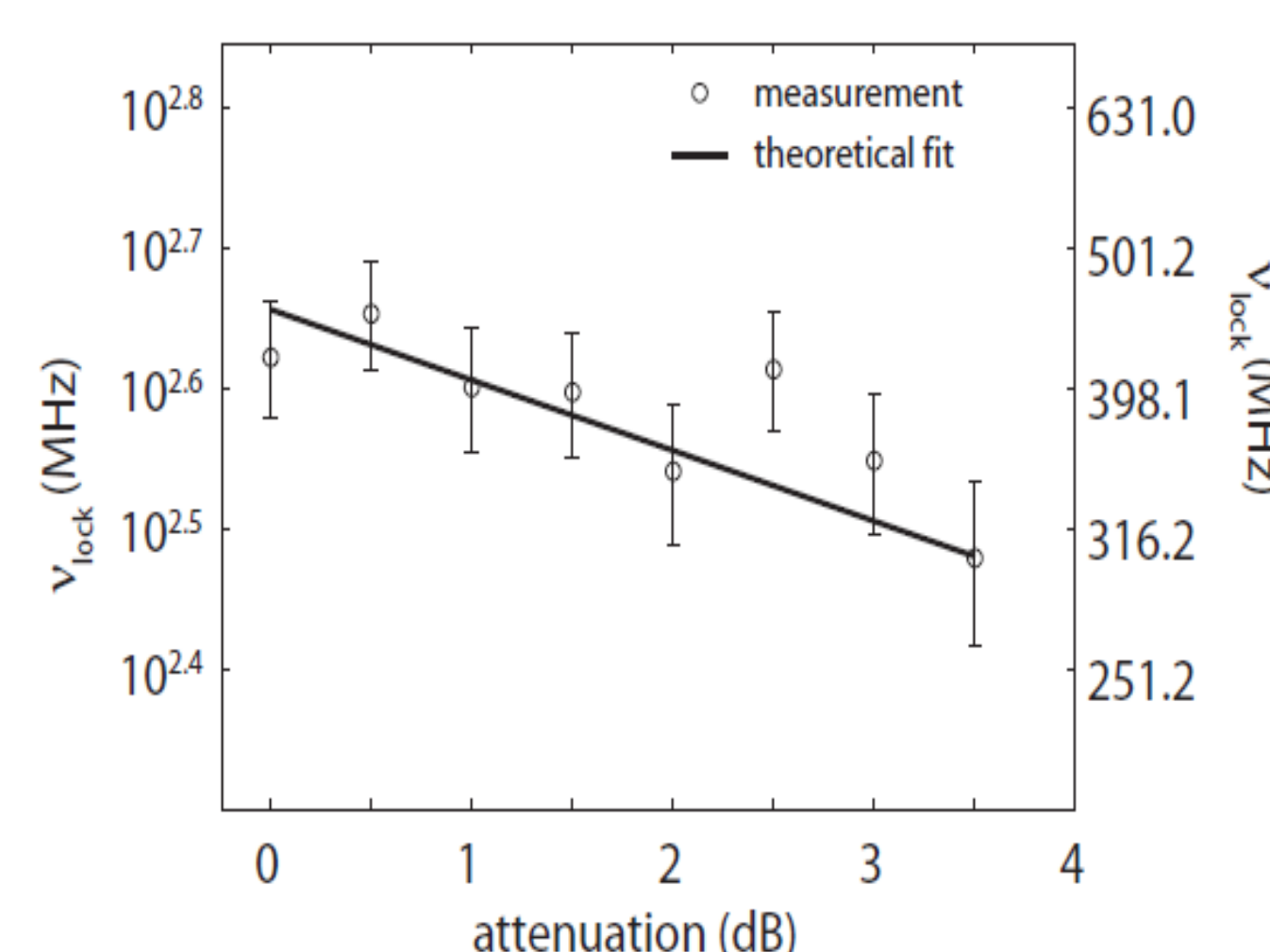
- Investigate the potential to build WECSL arrays with locked frequency and phase
- Verify injection locking as a tool to measure the Q-factor of complicated cavity with unknown losses.

#### Theory

- When subject to light injection from a Master laser, the frequency of the Slave laser could be locked within the range

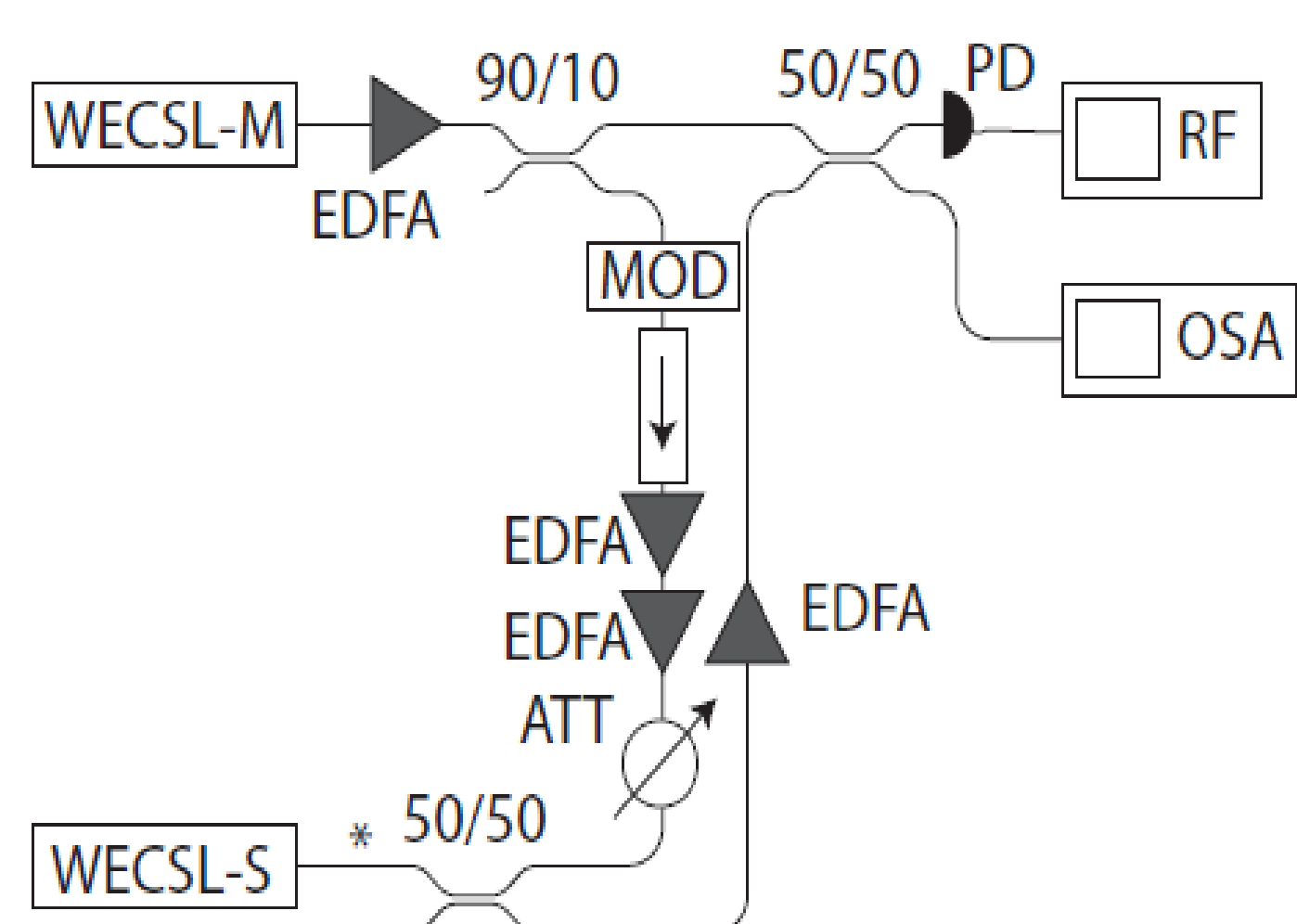
$$\nu_{lock} = \frac{\nu_{SL}}{Q} \sqrt{\frac{P_i}{P_{SL}}}$$

#### Main result



- Successful injection locking observed
- Estimated Q-factor =  $7.7 \cdot 10^4$
- Q-factor inferred from measured WECSL linewidth =  $1.5 \cdot 10^5$

#### Experiment setup



### High precision wavelength estimation

#### Goal

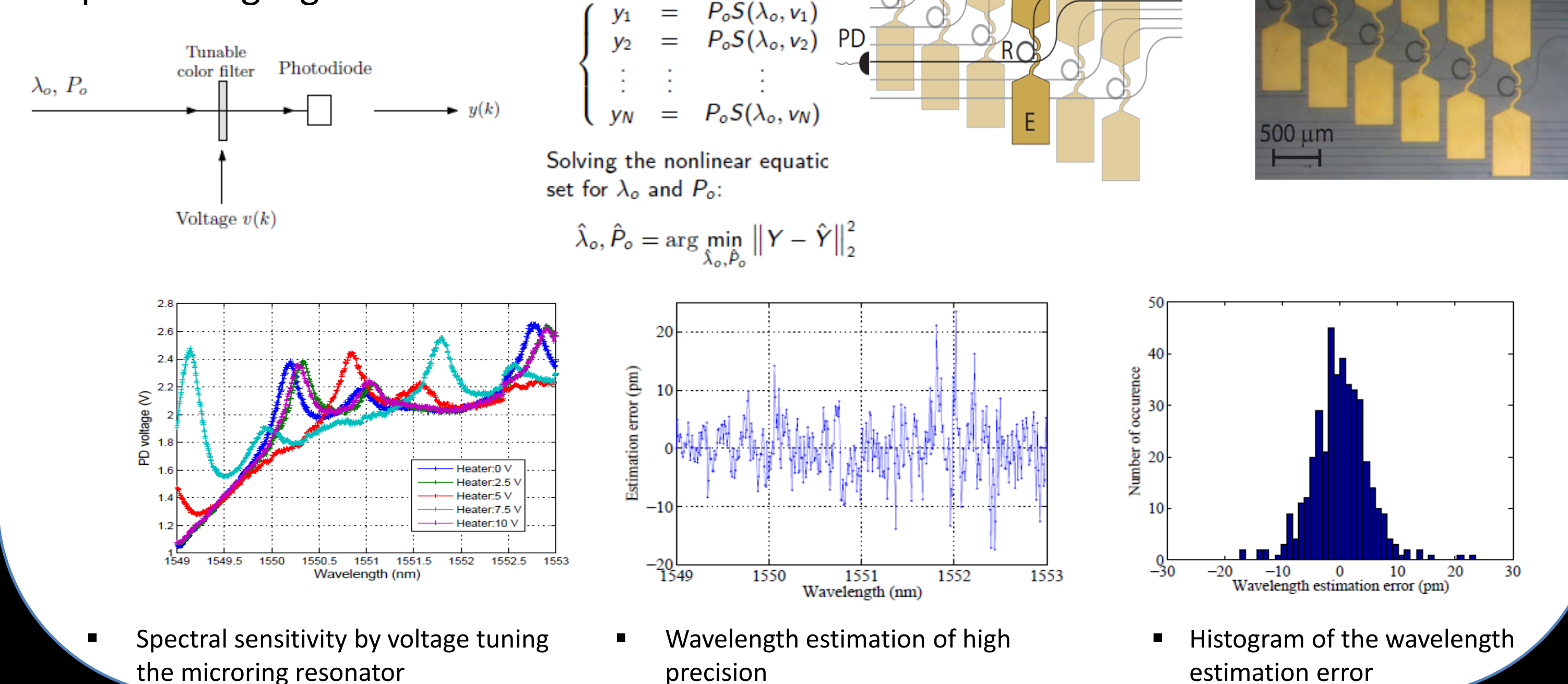
- Accurate wavelength monitoring devices for all integrated optics

#### Method

- Measuring detected signal from voltage tunable microring resonator + smart signal processing algorithm

#### Layout

#### Microscope picture



- Oldenbeuving, R.M., Klein, E.J., Offerhaus, H.L., Lee, C.J., Song, H. & Boller, K.J., "25 kHz narrow spectral bandwidth of a wavelength tunable diode laser with a short waveguide-based external cavity", *Laser physics letters*, **10**(1), 015804-1-015804-8.
- R Oldenbeuving, C.J. Lee, P.D. van Voorst, H.L. Offerhaus, K.-J. Boller, "Modeling of mode locking in a laser with spatially separate gain media", *Optics express*, **18**, 22996-23008 (2010).
- Oldenbeuving, R.M., Song, H., Schitter, G., Verhaegen, M., Klein, E.J., Lee, C.J., Offerhaus, H.L. & Boller, K.J., "High precision wavelength estimation method for integrated optics", *Optics express*, **21**(14), 17042-17052.